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Epidemiology and Pathology of Chicken Cholera

EDINBURGH: 1915

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SOME POINTS IN CONNECTION WITH THE

EPIDEMIOLOGY AND PATHOLOGY OF CHICKEN CHOLERA

Edinburgh and East of Scotland College of Agriculture

SOME POINTS IN CONNECTION WITH THE

EPIDEMIOLOGY AND PATHOLOGY OF CHICKEN CHOLERA

TOGETHER WITH A

DISCUSSION ON WHITE DIARRHŒA IN CHICKS

BY

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EPIDEMIOLOGY AND PATHOLOGY OF CHICKEN CHOLERA.

In this article it is proposed to deal with some questions relating to Chicken Cholera and arising from observations made during an outbreak of the same in the year 1914-1915. In the premises where the epidemic occurred poultry-rearing was commenced on new ground with entirely new plant at the beginning of 1914. The "intensive" system of poultry-rearing was used, and the eggs were hatched in incubators. On March 10 twelve dozen Rhode Island Red eggs were obtained from one source, and these were hatched on April 3. When the chicks were five days old they began to show signs of "white diarrhœa," and died at the rate of three to four a-day up to the 26th of April. Out of ninety hatched about sixty died from this condition. Chicks from eggs and day-old chicks of the white Leghorn and Wyandotte breeds were introduced to the run from April 9 on to the end of May, but white diarrhœa did not appear amongst these. The birds remaining after the outbreak continued apparently quite well during the summer, and appeared to thrive, except that one of them in the summer-time took a twist in its neck, which could not be straightened, the neck being bent and rigid.

On or about the 14th December, however, an epidemic commenced among them. The hens began to run at the nose and sneeze and go off feed. There was glairy mucus in the mouth, and out of about 200, forty had exudate and ulcers in the mouth. The eyes and sides of the face were swelled in others. No evidence of epithelioma contagiosum was present. The heavy breeds—the Rhode Island Reds and Wyandottes—were worst, while a great number of the Leghorns showed no outward symptoms of being affected. The disease continued among

them until about the middle of January 1915. At that time the catarrhal symptoms disappeared more or less, but a new symptom in the form of paralysis began to appear, this time affecting chiefly the Leghorns. The hens affected lay about, could not get into their nests, and could not jump on to the dropping boards at night. They were so weak in their legs that if touched on the crop with the toe of the boot they sat down on their tails. When picked up in the hands it was particularly noted that they were trembling all over. Certain of them were noted to be in a state of spasticity at times, their legs stretched out behind them and unable to be straightened. Two of them about the end of January also showed this spasticity in the form of "Swan neck"—*i.e.*, the neck could not be straightened. They continued, however, to eat their food greedily; but occasionally feeding was a difficult proceeding for them, on account of their inability, owing to the paralysis, to direct their head towards their food. Even when paralysed and hardly able to move, however, their combs were red and some of them continued to lay. The paralysis improved greatly through time, and in many cases the birds recovered almost entirely. Diarrhœa, though present in some cases, was not a marked symptom even in the acute stages of the disease prior to the outbreak of the paralysis.

The run was visited by me on the 3rd of April 1915, when the hens were seen to be active, vivacious, greedy of food, and red-combed. From 180 hens ninety eggs per day were being obtained. About nine of the birds, however, were seen to be more or less paralysed, some of them badly. One particularly was noticed which, though very unsteady on its legs and easily knocked over, came up to the owner inviting notice to be taken and pecking at her boots. The cases at this time were entirely confined to the Leghorns, none occurring among the Wyandottes or Rhode Island Reds.

The following are the notes on some of the cases on which post-mortems were obtained at this time. No case was obtained during the progress of the catarrhal symptoms, but, as mentioned before, the paralysis began to be noticed just when the catarrhal condition was abating. It has further to be noted that though the Leghorns did not exhibit to the same degree the catarrhal symptoms, many of them were undoubtedly

affected, while they fell victims in a larger degree to the paralysis.

LEGHORN 1.—March 31. Very badly paralysed. Killed and sent in for examination. Very emaciated. Nothing noticed post mortem except a white patch at the apex of the heart, and old-standing grey consolidated patches at the root of the lung. Cultures were made from the lung lesions, the heart-blood, and the spleen. About 300 colonies resembling the chicken cholera organism were obtained in a pure condition from the lung lesion, two colonies of the same organism from the spleen, while nothing grew from the heart-blood. The reaction of this organism, as of the others to follow, will be given in tabular form later.

WYANDOTTE 1.—March 31. No signs of paralysis. The bird appeared to be quite well the previous day, but was found dead the morning after: the cause of death was found to be an extensive peritonitis. Films of the pus showed the presence in pure culture of a typical bipolar staining organism. Cultures were made and showed a pure extensive growth of a chicken cholera-like organism.

BROWN LEGHORN 1.—Although this case did not occur in the same hen-run it is included here, owing to its resemblance to the last case and also to certain points in connection with its history. It died about the 4th of April, along with other three hens which exhibited the same symptoms. It appeared to have died very suddenly. Post mortem it was found to be in good condition, and the comb was red. There was glairy mucus in the mouth. The feathers around the anus were matted together with fæces. Evidently there had been some diarrhœa. The organs of the body appeared quite healthy except for some peritonitis and the presence in the peritoneum of a quantity of exudate. Nothing grew in the cultures made from either lung, liver, and heart-blood, while from the peritoneum and spleen a pure culture of an organism resembling that of chicken cholera was obtained. This case is interesting not only from its resemblance to the last case, but also from the fact that it occurred in a run where there was no evidence of an epidemic being in progress. It is true that three other hens had died about the same time, but these were the only deaths which had occurred during the year.

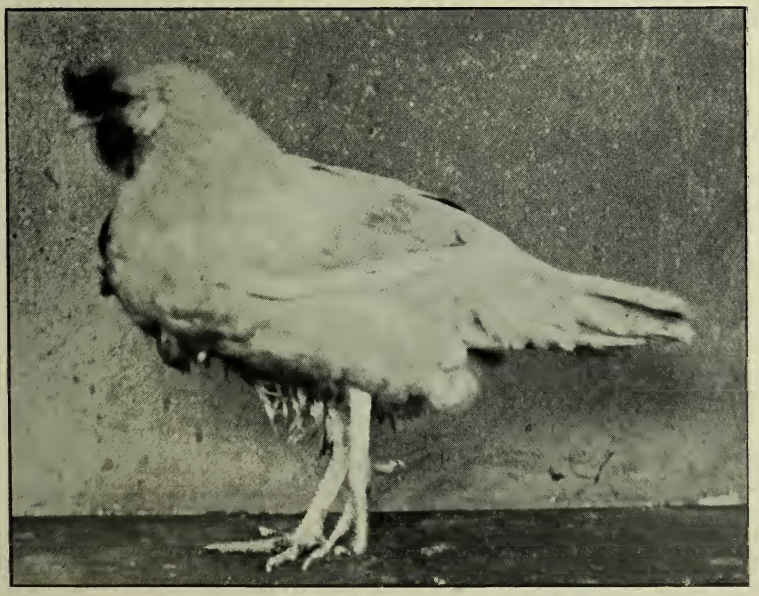
On the 6th of April six paralysed hens were obtained from the original run and brought into the laboratory for observation. Some were totally paralysed in the legs, some were weak and staggery, while others were more or less lame in one leg. In spite of this all of them were very red-combed, all very alert and active, all in good feather, and all had a very good appetite. While all could more or less stand when they came in, all with one exception were down and paralysed, and unable to get up, in the course of a few weeks. In some of them the fine tremor mentioned previously was very noticeable, especially if the lame leg was held up.

Leghorn 2.—April 6. Entirely lost power of both legs, unable to stand; weight 1350 grammes; very rosy-combed, clear-eyed and alert. Very good appetite; in good feather; seems quite comfortable. When it tries to get up it stretches out its wings and tries to raise itself on their tips; breathing is regular and easy; no running at eyes or nose; no diarrhœa. This hen laid an egg on April 5. Rectal temperature 41·2° C.

The hen was killed with coal gas and immediately examined. It was very emaciated. There was an egg ready for laying in the shell gland, and about a dozen large yolks in the ovary. There was a white spot at the tip of the heart. There was no disease in any of the bones or joints and no sarcocysts in the muscles. All the other organs appeared healthy. No growth was obtained in cultures made from the lungs (both), the spleen, oviduct, shell gland, heart-blood, peritoneum, or eggs in the ovary.

Leghorn 3.—Could walk about when brought into the laboratory two days ago. It is unable to stand to-day, April 8, and lies sprawling about; its comb is very red, it eats its food well, is quite alert and in good feather. When held on its back in order that the temperature may be taken its legs though unrestrained are not moved. Temperature is 41·6° C. Diarrhœa is present and the feathers around the anus are soiled and matted together. So little disturbed is it that when lying down it is constantly preening its feathers. Weight is 1320 grammes. The wings are quite strong. Killed with coal gas. Nothing abnormal was seen post mortem except a white spot at the top of the heart. The hen was not in laying condition, but the ovary was full of small yolks. Joints

LEGHORN 2 (lying on table). Mentioned in text. Showing total helplessness owing to paralysis of the legs.



LEGHORN 4. Mentioned in text. Showing paralysis in the left leg. The blurring of the photograph of the left leg is due to the tremor mentioned in the text.

examined and found healthy. No growth was obtained in cultures made from the right lung, oviduct, duodenum (three cultures), small intestine, left lung, heart-blood, peritoneum, trachea, spleen, shell gland, or ovary. In two cultures made from the small intestine three small colonies grew in each; from the rectum two cultures were made and in each a pure culture of a chicken cholera-like organism grew. It showed typical bipolar staining, and its sugar reactions will be discussed later.

Leghorn 4.—April 14. Brought in eight days ago; was lame in left leg when brought in. This lameness still remains. The leg is not painful. Tremor in it when it is held up. Red-combed; alert; eating food well; no signs of pain; lean; weight 1220 grammes. The legs are definitely paralysed, as there is no swelling or pain in any of the joints, and the muscles of the leg are much wasted. The rectal temperature is 42·1° C. Nothing abnormal was found post mortem except emaciation. The bones and joints were quite healthy. No growth of any kind was obtained from the oviduct, shell gland, left lung, heart-blood (two cultures), spleen, or peritoneum. From the right lung was obtained a good growth of a mixture of large and small colonies. From the left lung culture a pure growth of small colonies was obtained. In two cultures from the duodenum pure extensive growths of a small colony were obtained. In two cultures from the small intestine similar pure cultures of small colonies were obtained. In two cultures from the rectum extensive growths of two organisms were obtained, a small one present in much larger amount, and evidently the same as those formed in duodenum and small intestine, and a larger one. The reactions of these organisms will be found in the table.

Leghorn 5.—This hen had been brought in on April 6, and had been kept in the laboratory till May 20. It took the ground about a fortnight ago and has remained in this condition since. The temperature is 41·6° C. The tail feathers are matted together with fæces. There is a sour-smelling diarrhœa present. It is unable to stand. Its wings are not paralysed; very red in comb, appetite good, alert and intelligent. It is, however, very easily rendered breathless. If it struggles a little, it opens its mouth and gapes, while its glottis

is pushed strongly up and opens and shuts strongly. It was killed, and post mortem there was found a white spot at the apex of the heart. The intestine was very inflamed and filled with mucus-like fluid. All the bones of the body were found to be thinned, softened, and their shafts filled with red bone marrow. The shortness of breath during life was found to be due to the sinking in of the chest-wall owing to this softening.

No growth was obtained in cultures from the spleen, heart-blood (two cultures), trachea, left lung, right lung, ovary (two cultures). Five cultures were made from the small intestine. In two of these about fifty small colonies to ten large ones were present.

CHICKEN 1.—This died of white diarrhœa. It was hatched from bought-in eggs. It was five days old, and was first noticed ill to-day, April 8. It was alive when sent off to the laboratory, but died during transit. Post mortem was performed at once. There was found congestion of the lungs, non-absorption of the yolk-sac, while the anus was entirely closed by means of a hard, white, gritty, homogeneous mass. This material appeared to be the white material, in a dried condition, to which the disease owes its name. Above this mass the gut was very distended and full of unaltered seeds (? grain). No growth was obtained in cultures made from the liver, trachea, heart-blood (two cultures). From the right and left lung, as also from the spleen and one heart-blood culture, were obtained pure cultures of a small colony. From the duodenum a pure culture of a chicken cholera-like organism. The rectum showed a mixture of a large number of various organisms. (See further cases of this disease in Appendix.)

In regard to Table I., attention should first be drawn to the variability in the reactions of the organism of chicken cholera as exhibited in columns 18, 19, and 20. The organism in column 18 was obtained in pure culture from the heart-blood of a case of typical chicken cholera. The reactions given in column 19 were obtained when the organism was injected for the first time into the peritoneal cavity of a guinea-pig, and the peritoneal exudate after the animal had lived for about twelve hours was used to inoculate the various media. In this case care was taken to make sure that the peritoneal

	1.	2.		16.	17.	18.	19.	20.
	Leghorn.	Wyandoite 1. — Peritoneum.	B Le 1 to	Chicken 1. — Duodenum large colonies.	Book Characters of one strain of Chicken Cholera.	Chicken Cholera Org. from undoubted case of the disease.	Reaction given when tubes were inoculated direct from peritoneal fluid of G.P. which had been injected intraperitoneally with culture of typical chicken cholera the day previous.	Chicken Cholera after intensification by *passage* through a series of animals.
Glucose . .	A+G	A+G		A+G	O	A	A	A+G
Lactose . .	A+G	A+G		A+G	O	A	A	A+G
Mannite . .	A+G	A+G		A+G	O	A	A+G	A+G
Raffinose . .	A+G	O		A+G	O	O	O	A+G
Dextrin . .	A+G	A+G		A+G	O	A	A+g	A+G
Lactose N.R.	A+G	A+G		A+G	O	O	O	A+G
Galactose .	A+G	A+G		A+G	O	A	A+g	A+G
Maltose . .	A+G	A+G		A+G	O	A	A+g	A+G
Salicine . .	A	A		O	O	O	O	A+G
Cane . . .	A	O		A+G	O	O	O	A+G
Inulin . .	O	O		O	O	O	O	O
Sorbite . .	O	O		A+G	O	O	O	A+G
Adonite . .	O	O		O	O	O	O	O
Dulcite . .	O	O		O	O	A	A	A+G
Nitrites . .	+	+	t	+	?	+	+	+
Indol . . .	+	+		+	O	O	O	+
Gelatine . .	growth no liquef.	growth no liquef.	? g no	growth no liquef.	slight gr. no liquef.	slight gr. no liquef.	slight growth no liquef.	good gr. no liquef.
Motility . .	?–	?–		?	O	O	O	+
Litmus M. .	A+C	A+C		A+C	?	A?	A+C	A+C
Morphological.	Polar staining in guinea-pig peritoneum.	Typical polar staining bacillus in original exud.		Typical polar staining in guinea-pig peritoneum.	Typical polar staining.	Typical polar staining.	Typical polar staining.	Typical polar staining.
Gram.	neg.	neg.	r	neg.	neg.	neg.	neg.	neg.

A = acid production ; ? = doubtfully present ; D = decolorisation.

Organism Le .
Organism W small to 1 large in small intestine.
Organism Bl ure culture in right and left lung,
Organism Le d in pure culture in duodenum.

TABLE I.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
	Leghorn.	Wyandotte 1. — Peritoneum.	Brown Leghorn. — Peritoneum.	Leghorn 3. — Rectum.	Leghorn 4.								Leghorn 5. — Intestine large colony.	Leghorn 5. — Intestine small colony.	Chicken 1. — Left Lung small colonies.	Chicken 1. — Duodenum large colonies.	Book Characters of one strain of Chicken Cholera.	Chicken Cholera Org from undoubted case of the disease.	Reaction given when tubes were inoculated direct from peritoneal fluid of G.P. which had been injected intraperitoneally with culture of typical chicken cholera the day previous.	Chicken Cholera after intensification by *passage* through a series of animals.
					Intestine small colony.	Duodenum small colony.	Right Lung small colony.	Left Lung small colony.	Rectum small colony.	Right Lung large colony.	Right Lung large colony.	Rectum large colony.								
Glucose . .	A+G	A+G	A	A+G	O	A?	A	O	A	A	A	A+G	O	O	A	A+G	O	A	A	A+G
Lactose . .	A+G	A+G	O	O	O	O	A	O	O	O	O	A	O	O	A	A+G	O	A	A	A+G
Mannite . .	A+G	A+G	A	A+G	O	O	O	O	O	A+G	A	A+G	O	O	O	A+G	O	A	A+G	A+G
Raffinose . .	A+G	O	O	O	O	O	A	O	O	A	A	A	O	O	A	A+G	O	O	O	A+G
Dextrin . .	A+G	A+G	A	A+G	O	A	A	A	A	A	A	A+G	A	A	A	A+G	O	A	A+g	A+G
Lactose N.R.	A+G	A+G	O	O	O	O	O	O	O	O	O	A+G	O	O	A	A+G	O	O	O	A+G
Galactose .	A+G	A+G	A	A+G	O	A	O	O	A	A	A	A+G	A?	A	A+g?	A+G	O	A	A+g	A+G
Maltose . .	A+G	A+G	A	A+G	O	O	O	A	A+g?	A	A	A+g?	A	O	A	A+G	O	A	A+g	A+G
Salicine . .	A	A	O	A	O	O	O	O	O	O	O	A	O	O	O	O	O	O	O	A+G
Cane . . .	A	O	O	O	O	O	A	O	O	A	A	A	O	O	A	A+G	O	O	O	A+G
Inulin . .	O	O	O	O	O	O	O	O	A	O	O	A	O	O	O	O	O	O	O	O
Sorbite . .	O	O	O	A+G	O	O	O	O	O	O	O	A+G	O	O	O	A+G	O	O	O	A+G
Adonite . .	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
Dulcite . .	O	O	O	...	O	O	O	O	O	O	O	O	A??	O	O	O	O	A	A	A+G
Nitrites . .	+	+	trace	+	trace	trace	trace	trace	trace	trace	trace	+	trace	trace	trace	+	?	+	+	+
Indol . . .	+	+	O	+	O	O	O	O	O	O	O	+	O	O	O	+	O	O	O	+
Gelatine . .	growth no liquef.	growth no liquef.	? growth no liquef.	growth no liquef.	? growth no liquef.	? growth no liquef.	? growth no liquef.	? growth no liquef.	? growth no liquef.	? growth no liquef.	? growth no liquef.	good gr. no liquef.	no liquef.	no liquef.	? growth no liquef.	growth no liquef.	slight gr. no liquef.	slight gr. no liquef.	slight growth no liquef.	good gr. no liquef.
Motility . .	?–	?–	–	–	O	O	O	O	O	O	O	?	O	O	O	?	O	O	O	+
Litmus M. .	A+C	A+C	O	O	A?	A?	A+C+D	A	A+C+D	A	A	A+C+D	O	O	A	A+C	?	A?	A+C	A+C
Morphological.	Polar staining in guinea-pig peritoneum.	Typical polar staining, bacillus in original exud.	Typical polar staining.	Typical polar staining in guinea-pig peritoneum.	Typical polar staining.	Typical polar staining.	Typical polar staining.	Typical polar staining.	Typical polar staining.	Typical polar staining.	Typical polar staining.	Typical polar staining.	Typical polar staining.	Typical polar staining.	Typical polar staining.	Typical polar staining in guinea-pig peritoneum.	Typical polar staining.	Typical polar staining.	Typical polar staining.	Typical polar staining.
Gram.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.	neg.

A = acid production ; A+G = acid and gas production ; O = no reaction ; C = clot ; g = small amount of gas production ; + = present ; – = absent ; ? = doubtfully present ; D = decolorisation.

Organism Leghorn 1, found pure culture in lung and spleen.
Organism Wyandotte 1, found pure culture in peritonitis.
Organism Brown Leghorn, found pure culture in peritonitis.
Organism Leghorn 3, found pure culture in rectum.

Organisms Leghorn 4, found present as described.
Organisms Leghorn 5, found present in ratio of 5 small to 1 large in small intestine.
Organism Chicken 1, small colonies found in pure culture in right and left lung, spleen, and heart-blood ; large colonies found in pure culture in duodenum.

fluid contained only the original organism injected. In column 20 is given the reaction of this same organism after it had been intensified by *passage* through a series of animals, an occurrence to which attention has been drawn by Dr Wang and myself (1). In column 17, on the other hand, are given the reactions usually ascribed to the organism in the text-books (Lignières) (2) and (Hutyra) (3).

In considering, therefore, with these facts in view, the table as a whole, it will be seen that an organism of one of these types was isolated from all the cases except one[1] in this epidemic, and further, as the notes of the cases show, in pure and extensive cultures. In some of the cases the organism is frankly of the ordinary chicken cholera type, in others it belongs to some of the intermediate groups.

With the exception of the white diarrhœa case in the chicken, all the cases in consideration here were obtained after the disease had settled down into the more or less chronic paralytic form. No material was obtained while the acute catarrhal symptoms were in evidence. Consequently the organisms, when obtained in the organs of the body of such cases, were generally found in more or less chronic lesions such as foci of inflammation in the lungs. On the other hand, in these chronic cases the organism was usually found, often in practically pure culture, even in its attenuated form, in the intestines.

Cases such as Leghorn 4 and Leghorn 5 are evidence of the truth of this statement, while in the case mentioned above (case Leghorn 2), in which no organisms of any kind were obtained in cultures, no cultures were made from the intestine.

As mentioned above, no material for examination was obtained while the disease was in its catarrhal form. This was unfortunate from the point of view of a complete study of this epidemic. However, I possess material from an acute catarrhal epidemic of the same kind, occurring this time, however, in pigeons. The following are notes on the cases:—

Case 1. Pouter pigeon, male; very lean; well feathered; no diarrhœa; coughing and sneezing, tenacious mucoid material in the mouth; at the frænum of the tongue there is a large piece of yellowish white membrane adherent to the mucous membrane. There is also whitish yellow muco-pus coming from

[1] Cultures were not made from the intestine in this case.

the trachea; trachea is very congested, when seen through the vocal chords. The animal was killed. Post mortem nothing abnormal was seen in the various organs of the body. There were no intestinal parasites present. No growth was obtained from the heart-blood, but an almost pure growth of small colonies was obtained from the trachea. No culture was made from the intestines.

Case 2 (from same epidemic). There was no membrane in the mouth of this case. There was whitish muco-pus coming from the trachea. There were no *syngami tracheales* present. The spleen was slightly enlarged. Pure extensive cultures of an organism were obtained from the heart-blood and spleen.

Case 3 (from same epidemic). Very lean; no membrane in mouth, but mucus present; spleen much enlarged. Pure extensive cultures of an organism were obtained from the heart-blood and spleen. The reactions of these organisms along with those of cases 1 and 2 are now given in Table II.

TABLE II.

	Case 1.	Case 2.		Case 3.	
	Trachea.	Spleen.	Heart-blood.	Spleen.	Heart-blood.
Glucose	A	A+G	A+g	A+G	A+g
Raffinose	O	A+G	O	—	—
Mannite	O	A+G	O	A+g?	A+G
Cane	O	A	O	O	O
Adonite	O	O	O	O	O
Indol	O	+	+	O	O
Litmus M.	O	A+C	A+c?	O	O
Lactose	O	A+G	?	O	O
Dextrin	A	A+G	A+g	A+g	A+g
Lact. Neut. Red.	O	A+G	O	O	O
Inulin	O	A	O	O	O
Dulcite	O	A+G	A+G	A+g	A+g
Gelatine	?	growth, no liquef.	growth, no liquef.	slight, no liquef.	slight, no liquef.
Morphology	bipolar	bipolar	bipolar	bipolar	bipolar
Galactose	A	A+G	A+g	A+g	A+g
Maltose	A	A+G	A+g	A+g	A+g
Salicine	O	O	O	O	O
Sorbite	O	A+G	A+g	A+g	A+g
Nitrites	trace	+	+	+	+
Motility	O	O	O	O	O
Gram.	neg.	neg.	neg.	neg.	neg.

A = Acid production.
A+g = Acid, but small amount of gas produced.
O = No change or not present.
— = Not tested.
A+G = Acid and gas production.
+ = Positive.
? = Doubtful production or growth.
c = Small amount of clot.

The organism from case 1 produced rapidly fatal issue when injected into guinea-pigs. A pigeon was inoculated in the larynx with a pure culture of this organism, and a week after was noticed to be coughing. There were greyish-yellow spots on the larynx, and there was a discharge of slimy mucus from the mouth. It will be seen, therefore, that from case 1 a pure growth of undoubted chicken cholera of the attenuated form was cultivated from the trachea, while from cases 2 and 3, from the same epidemic, more intensified cultures of the same organism were obtained from the spleen and heart-blood in pure culture. It is to be noted, however, that the reactions of the organism derived from the spleen of case 2 differed slightly from those derived from the heart-blood of the same case and from the heart-blood and spleen of case 3, which very closely resemble one another.

A note has now to be added on the microscopic findings in the spinal cords of the affected animals. Dr Dawson, Neurological Histologist to the laboratory, has very kindly examined them in all the cases, and reports that he could find nothing abnormal. This is in keeping with what occurs in the paralysis occurring in other hæmorrhagic septicæmia affections, where unless the condition has lasted some considerable time no change can be found. This occurs for instance in louping-ill, a variety of hæmorrhagic septicæmia in the sheep (4).

The case of white diarrhœa in the chicken now falls to be discussed more fully. Rettger first described a bacillus in 1900 as the cause of this condition. In 1908, along with Harvey (5), he again discusses the subject. He describes the organism as being a long slender bacillus ·3–·5μ broad by 1–2·5μ long with slightly rounded ends. It usually occurs singly. It is non-motile, does not liquefy gelatine, is non-chromogenic and facultatively (an ?) aerobic; microscopically he states that it resembles the typhoid bacillus; it does not retain gram, and no spores are formed. It is killed by an exposure at 56°-57° C. for fifteen minutes. The growth on agar is delicate, and the same occurs on glycerine agar. On potato there is little growth, while on litmus milk there is no change for 48 hours, and then a doubtful production of acid. No clotting occurs, however. No change is produced in maltose, lactose, cane, inulin, and dextrin, but acid and gas is produced in glucose and mannite.

There is no indol production and no nitrite formation. He calls it the *Bacterium pullorum*, and states that it belongs to the colon-typhoid-dysentery group. It, however, differs from the well-known varieties of this group.

In 1909 (6) he has a further article on the subject. In it he states that different strains vary in their gas-producing power in dextrose broth. Some of the organisms which he has isolated have failed and still fail to produce gas in this medium. On the other hand, two particular strains fermented the sugar with acid and gas production. The more active fermenter of these two, however, lost this property within a period of seven or eight months.

All strains produced acid in glucose broth. None affected lactose. Mannite was fermented by some strains but not by others. He emphasises the fact that fatal septicæmia in chicks and ordinary white diarrhœa in them are one and the same disease, and are both caused by *Bacterium pullorum.* Rettger and Stoneburn, quoted by Gage (*vide infra*), found that the cause of the original source of infection with *B. pullorum* was the hen. Experiments were conducted in which cultures were used which had been isolated from the ovarian tissue of hens. These hens had laid eggs containing the specific organism. The eggs when hatched had produced "white diarrhœa" chicks.

Gage (7) in 1911 confirmed this view.

The next writer on the subject is Jones (1912-13) (8). He states that in 1909 he confirmed the view that *B. pullorum* is the cause of white diarrhœa. He stated then that the infection took place either through the egg or by contact in the incubator with chicks which had acquired the disease through egg infection, or by the placing of chicks in contaminated surroundings. He found the organism present in the egg. He could not produce the disease in adult fowls by feeding or by intravenous injection of pure cultures of the organism. Chicks are most susceptible to the disease during the first twenty-four hours of life. Jones states further that Rettger and Stoneburn have perfected a method for the examination of eggs for *B. pullorum.* He quotes them as making the statement that the infected female chicks which survive the disease continue to carry the organism in their bodies, not in their various organs as when they are young and visibly infected, but locally in the ovary.

In other words, such fowls have become permanent bacillus-carriers. Their examination of the ovaries of half-grown pullets gave them strong evidence for this belief.

Jones stated that in 1911 he clearly proved that a number of adult females which had been infected when young chicks and had overcome the disease became harbourers of the organism. *B. pullorum* was found in the eggs and ovaries of some of them. Jones further describes an acute disease in adult fowls due to the same organism. The symptoms include loss of appetite and in some cases diarrhœa. The disease is a true septicæmia.

In dealing with this disease some further papers showing the relation between this organism and the organism causal of a disease known as fowl typhoid have to be considered. Thus Theobald Smith and Carl Ten Broeck (9) discuss the relationship between these two organisms. In their comparison they used a strain of *B. pullorum* obtained originally from Rettger in 1899 (*B. pullorum* I.), one from Moore of Cornell University in 1911 (*B. pullorum* II.), one received from Frothingham (*B. pullorum* III.), and two isolated by themselves from young chicks in 1914 (*B. pullorum* IV. and V.).

They found that the *B. pullorum* strains do not act on maltose, while the fowl typhoid strains, two in number, do, producing acid only, however. They discuss some points in the literature regarding the action of these two organisms on dextrose and mannite. Moore found that no gas was produced with the fowl typhoid. Rettger and Harvey found acid and gas production in both sugars with *B. pullorum*, while Jones stated that while this organism always produced acid it sometimes did and sometimes did not produce gas.

Smith and Ten Broeck found that while no gas was produced in dextrose or mannite by the fowl typhoid strains in their possession or by *B. pullorum* I., the II., III., and V. strains produced acid and gas of various amounts in both sugars. Strain IV., however, produced gas in dextrose, but none in mannite. They found, further, that while the fowl typhoid strains produced an alkaline reaction as tested by phenolphthalein after nineteen days, the *pullorum* strains did not. Again gas was produced in fermentation tubes containing milk by the *pullorum* strains II. to V., but not by the *pullorum* I. and fowl typhoid I. and II. strains. They state that the gas

production of *B. pullorum* is of a fluctuating character which seems to disappear during artificial cultivation. They regard the statement made by Hadley that the fowl typhoid bacillus probably belongs to the fowl cholera group as disproved by so many facts that it need not be specially considered.

Theobald Smith and Ten Broeck (10), further, while discussing the organism of fowl typhoid in regard to its agglutination reactions as compared with human typhoid, give some additional facts about its reactions. They describe the symptoms observable in this disease as described by Moore. The disease would appear to be characterised in the main by changes in the blood. The red blood corpuscles progressively decrease to two-thirds or one-half of the original number, while the white blood corpuscles increase and may become seven to ten times as numerous as under normal conditions. He was therefore induced to call the disease infectious leukæmia. Two strains of the bacillus were used by them in this investigation, one obtained from Moore in 1898, and the other isolated from an outbreak in Rhode Island by themselves. Morphologically, according to Smith and Ten Broeck, the organism does not resemble the typhoid bacillus, but rather the hog cholera, in showing a lightly stained oval centre, and this oval unstained centre is larger than in the hog cholera organism. They state that it is not improbable that the absence of motility and the tendency to a bipolar stain may have misled some workers in supposing that they were dealing with the true fowl cholera organism. Indol may or may not be produced. After long standing in the incubator, and using phenol-phthalein as an indicator, alkali is produced. The organism produces acid in dextrose, lactose, cane, maltose, and mannite, while the reactions on salicine and raffinose are much the same as in *B. pullorum.*

In discussing the facts before us it is extremely difficult not to believe that one is not dealing in all these cases with the same disease. The vagaries of the fowl cholera organism (as also of the other members of this group), as established by me on a great many strains, are very numerous. In fact, the link that joins them up, apart from a substratum of basal resemblances, is this very divergency and capacity of mutation. Again, all the workers with *B. pullorum* who have had the

opportunity of examining a fair number of strains have noted this variability in the reactions of the organism, extending even the length of producing gas in sugars at one time and none at others with the same strain, and similar vagaries occur also with different strains. In connection with the *Bacillus pullorum*, the further fact has to be noted that it is capable of causing a disease in adult fowls indistinguishable from fowl cholera.

My own experience in this epidemic leads me to the belief that the organism which I obtained from the lungs, heart, &c., of the case of white diarrhœa is identical with the chicken cholera organism. Whether it is identical with the *B. pullorum* is a question which cannot with certainty be settled from the existing facts of the case.

As regards the fowl typhoid organism, Smith and Ten Broeck (*loc. cit.*) worked only with two strains, and these a long time after their isolation and after they had been grown on artificial media for a considerable time. There was time and opportunity thus for both strains to have settled down to uniformity of reactions. Possibly if these observers had used more recently isolated cultures, and a larger number of them, they would have found the variations described by me for chicken cholera and by American writers for *B. pullorum*.

There is one point, however, on which I would hesitate to give an opinion, and that is with reference to the production of alkali in litmus milk. I have not examined tubes of this medium inoculated with chicken cholera at a longer period than after forty-eight hours. Within this period, however, all changes may occur from no change, slight alkalinity, acid without clot, and acid with clot. The indicator used was Kubel and Tiemann's litmus solution. With *B. pullorum* there is no change within forty-eight hours, and after this a possible production of acid, according to the statements made in articles on the subject. It is quite possible, therefore, that this character may be subject to variation as well, and that the definite alkalinity observed (be it noted, however, after nineteen days) is one scene, possibly the last, in a shifting panorama.

With regard to the carrying on of the epidemic by means of the eggs, the points elucidated in this inquiry are as follows: Two of the hens died of acute peritonitis caused by a pure culture of the chicken cholera organism. None of the cultures

made from the ovaries or oviducts of any of the other cases showed a growth. Again, two dozen eggs were obtained from one day's laying from the hens among which the disease was prevalent, and at the time when it was occurring. Eggs also were obtained from the paralysed hens. These were incubated at 37° for forty-eight hours, the yolk and albumen broken up together and cultures on agar made from about ¼cc. of this mixture. In none of these cases was a growth of any kind obtained. Possibly the eggs had not been incubated long enough, or too few observations had been made. At any rate Marchiafava and Celli and Reynal, as also Barthelemy (quoted by Hutyra, *loc. cit.*), have shown the presence of chicken cholera organisms in eggs from hens affected with the disease. The last investigator produced typical chicken cholera in hens by causing them to eat such eggs.

A point may be considered here in reference to the occurrence of blood changes in the disease called fowl typhoid by Moore. On account of these changes, as mentioned before, he called the disease infectious leukæmia. A case in which profound alterations in the blood-forming organs was observed by me occurred in the epidemic recorded above. Leghorn 5 showed very marked changes indeed in all the bones of the body, the shafts being softened, thinned, and filled with what appeared to be red bone-marrow. Sections of the marrow showed it to be composed for the most part of polymorphonuclear leucocytes. No blood counts, however, were made on this bird, so that it is impossible to say whether the red blood cells were diminished and the leucocytes increased in number, as Moore found in his cases. The occurrence, however, of the bone-marrow changes is significant from the point of view of the possible identity of Moore's fowl typhoid with the disease observed in this epidemic. It has further to be noted that this condition was not observed in any of the other birds.

In trying to summarise this paper, it may be pointed out that evidence has been brought forward for the existence in the natural disease, chicken cholera, of strains of the *bacillus bipolaris septicus ovium* of very varying biological activity. Thus the experimental fact described by Dr Wang and myself (*loc. cit.*) finds support from such a natural occurrence. Evidence has been adduced also to show that in all probability white diarrhœa in chicks is caused by the chicken cholera

organism. The occurrence of paralysis shown by me to occur in an infection with another number of this group—louping-ill —and almost certainly of a toxic nature, has also been drawn attention to in this disease.

The disease has been compared from the bacteriological standpoint with the white diarrhœa and fowl typhoid or infectious leukæmia of American authors, and there would seem to be cogent evidence for the view that the three diseases are not other than identical. As regards fowl typhoid especially, the observance of profound bone-marrow changes in one of my cases is strong support for the view advanced here.

Some points also in connection with the symptomatology deserve mention. Fowl cholera is usually considered to be more or less an intestinal disorder, with marked diarrhœa as its symptom. In the epidemic, however, just observed, this symptom was conspicuous by its absence. The outward signs of the disease in this case were catarrh of the upper air-passages, together with membrane formation and ulcers in the mouth. When a fowl shows evidence of these symptoms, it is usually said to be suffering from "roup." This tendency to fix on certain localities of the body in certain epidemics is observable with other members of the *hæmorrhagic septicæmia* group. Thus the respiratory passages in some cases, and the intestinal canal in others, may be the sites of election in different epidemics. Again, chicken cholera is usually said to be a very fatal disease. This epidemic was characterised by its chronicity and low mortality. No case died while the acute catarrhal symptoms were in progress. The disease, further, is usually considered to be extremely infectious, and as evidence of this is often adduced the outbreak of the disease in several hen-runs at wide distances from one another, and where no known communication has existed between them. There is no attempt to be made here to show that chicken cholera is not very infectious *once it has broken out in a hen-run;* for it is indeed. An attempt, however, will be made to point out that the circumstances just stated are explicable in quite another fashion. The chicken cholera organism is known to be able to live as a saphrophyte in soil, manure, water, &c. (Huytra, quoting several authorities); the organism is also present in the respiratory passages and intestines of a large percentage of apparently healthy fowls. Such organisms, how-

ever, may be present and harmless for long periods until some secondary cause or causes intervene, which may lower the vitality of the animal, allow the organism to fasten on, and by so doing raise its virulence to such an extent that a true infectious disease is set up. I have already shown (*loc. cit.*) that with another member of this group—the *bacillus bipolaris septicus ovium*—which is present in the respiratory tract, &c., of apparently healthy sheep, the secondary cause which sets the disease going is a sudden chill, more or less profound. In this case these particular diseases—braxy and louping-ill—as far as one knows at present, would appear not to be infectious among adults; but as sheep on their pastures are widely separated from one another, and do not naturally come in close contact, it would be unwise to say that such infection does not take place. Indeed a well-known infectious disease, which forms the subject of report yearly by the chief veterinary officer of the German Government, and called infectious lung inflammation of sheep, or *septicæmia pleuriformis ovis*, is caused by the organism which I have shown to cause braxy and louping-ill. In this case the symptoms are those of catarrh of the respiratory passages, and the disease is regarded as being very infectious once it has broken out in a flock.

While, as I have stated above, there is as yet no evidence that braxy or louping-ill is infectious among adult sheep, there is evidence, however, that a ewe with louping-ill will almost certainly infect her lambs, causing in them the disease known as "white scour." Here again, while there is as yet not sufficient evidence to warrant one in stating that white scour in the lamb is infectious from lamb to lamb, yet there is every evidence for the corresponding disease in calves being considered very infectious indeed. Nocard states that this disease is due to a hæmorrhagic septicæmia organism, and I have brought forward evidence to show that the various coli organisms which Jensen holds to be causal may be in reality varieties of intensified hæmorrhagic septicæmia organisms.

One outstanding feature, therefore, in the whole of the hæmorrhagic septicæmia affections as observed in the fowl, the sheep, and cattle, is that while the organism may be the cause of both sporadic and sometimes infectious diseases in the adult, it may also be capable of causing infectious conditions usually associated with diarrhœa in very young animals. The

point has further to be noted that the adults may set this disease going among the young animals without themselves showing much evidence of it.

In conclusion, I would urge that in a large number of diseases attributable to members of this group, the existence of what one might term a super-infectivity should not be assumed as an explanation of certain phenomena of epidemiology until the resources of simpler and more probable theories, better according with the facts, are exhausted. Too much indeed has always been made of the view, unwarranted in most cases from the facts, that a case of virulent infectious disease must always arise from some previously existing well-defined case of the disease. If this case cannot be located, the assumption is nevertheless made that it must exist or have existed somewhere. In this way subsequent epidemics are traced to epidemics which have taken place on the same ground decades before, and infectious diseases arising in one locality, with no other cases of the disease occurring around, and no source of communication with disease places far distant forthcoming, are assumed to have arisen from these distant cases by a super-infectivity. The explanation offered here for their occurrence, however, is that the disease has arisen from the heightening of virulence of a semi-saprophytic organism by some secondary cause, a power of infection having been conferred on the organism in this process. One of the basal facts, moreover, of the group of diseases caused by the hæmorrhagic septicæmia organisms is, that it is characteristic of their epidemiology that sporadic cases may be produced at one time and devastating epidemics at another by the same organism.

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(8) Jones. Journ. Med. Research. 1912-13. Vol. XXVII.
(9) Theobald Smith and Ten Broeck. Journ. Med. Research. Vol. XXXI., 1914-15, p. 547.
(10) Theobald Smith and Ten Broeck. Journ. Med. Research. Vol. XXXI., 1914-15, p. 523.

APPENDIX.

Since the above was written four further cases of chickens suffering from white diarrhœa were obtained from the same hen-run. The owner states that she bought in 100 day-old chicks on May 8, 1915, and now, on June 18, she has only 15 left out of the 100. 35 of them died during the first fortnight, 15 of them on the fifth day.

The chickens were suffering from diarrhœa. In Nos. 1 and 2 nothing abnormal could be seen with the naked eye, in No. 3 there was a large spleen, while in No. 4 there was a large grey spleen, blood-stained effusion into the heart, and some extensive greyish-white irregular patches on the muscle of the heart. No coccidiosis was found either in smears or sections of the intestine. The sections of the intestine showed the lumen of the gut to be filled with pus cells and desquamated epithelium, while the mucous membrane was markedly infiltrated with pus cells. Cultures were made from various situations in each of the four cases, and the results of these cultures are given in Table III.

TABLE III.

	Case 1.	Case 2.	Case 3.	Case 4.
Spleen . .	Mixture of five small and 4 large colonies.	Pure culture of about a dozen small colonies.	Extensive growth of large colony with a few small colonies.	Pure extensive growth of small colony.
Small intestine	Uniform growth.	Chiefly large colony, but two small colonies.	Extensive pure growth large colony.	Pure extensive growth of small colony.
Liver . .	Six large colonies.	Several large colonies.	One large colony.	"
Heart-blood .	No growth.	No growth.	No growth.	"
Right lung .	Large colonies only.	14 large colonies and 60 small colonies.	Not done.	"
Left lung . .	Medium colonies present.	Large colony only.	Pure extensive growth of small colony.	"
	The large colonies were greyish-white, moist, and appeared all to belong to one kind. The small colonies were more translucent. The medium colonies appeared to be intermediate between these two.			

TABLE IV.

	I. Right lung large.	I. Spleen large.	I. Liver large.	I. Intestine large.	II. Intestine large.	II. Liver large.	II. Right lung large.	II. Left lung large.	III. Spleen large.	III. Left lung small.	III. Intestine large.	IV. Liver small.	IV. Heart-blood small.	IV. Intestine small.	IV. Right lung small.
Lactose N. Red	A+G	A+G	As in last organisms, Nos. 1 and 2	A+G	A+G	A+G	A+G	A+G	As in Number 6	A+G	As in Nos. 6 and 9	A?	A?	A?	A?
Nitrites	marked	marked		marked	marked	marked	marked	marked		marked		marked	marked	marked	marked
Litmus milk	A+C	A+C		A+C	A+C	A+C	A+C	A+C		A+C		O	Acid	A?	A?
Maltose	A+G	A+G		A+G	A+G	A+C	A+G	A+G		A+G		O	A+G	O	O
Raffinose	A+G	A+G		A+G	A+G	A+G	A+G	A+G		A+G		O	A+G	O	O
Galactose	A+G	A+G		A+G	A+G	A+G	A+G	A+G		A+G		A	A+g	A	A
Cane	O	O		A	A+G	A+G	A+G	A+G		A+G		O	A+g	O	O
Inulin	O	O		A+G	O	O	O	A+G		A		O	O	O	O
Salicine	O	O		A+G	A+G	A+G	O	O		Indol		O	O	O	O
Peptone	Indol	Indol		Indol	?	Indol	Indol	Indol		A+G		?	trace	?	trace
Dulcite	A+G	A+G		A+G	A+G	A+G	A+G	A+G		A+G		O	O	O	O
Sorbite	A+G	A+G		A+G	A+G	A+G	A+G	A+G		O		O	Acid	O	O
Adonite	O	O		A+G	A+G	O	O	O		A+G		O	O	O	O
Dextrine	A+G	A+G		A+G	A+G	A+G	A+G	A+G		A+G		A	A?	A	A?
Lactose	A+G	A+G		A+G	A+G	A+G	A+G	A+G		A+G		O	O	O	O
Glucose	A+G	A+G		A+G	A+G	A+G	A+G	A+G		A+G		A	A	A	A
Mannite	A+G	A+G		A+G	A+G	A+G	A+G	A+G		A+G		A	A	A	A
Gelatine	growth no liquef.	as in last organism		as in last organism	as in last organism	as in last organism	as in last organism	as in last organism		as in last organism		as in last organism	as in last organism	as in last organism	as in last organism
Gram	negat.														
Morphology	bipolar cocco bacillus														
Motility	absent														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

A=acid; G=large amount of gas; g=small amount of gas; A+G=acid and gas; O=no change; ?=doubtful presence; C=clot.

With regard to Table III., it should be noted that in Case 4 pure cultures apparently of the same organism were obtained from all the organs, even the intestine. With regard to the other cases, large, intermediate, and small colonies were obtained from the lungs, liver, and spleen. No growth was obtained from the heart-blood in any of these three cases. In the intestine in Cases 1 and 3 a large colony organism was obtained apparently pure, while in Case 2 a mixture of it and the small colony was obtained.

In Table IV. it will be seen that the organisms isolated from the right lung, spleen, and liver of Case I. are identical; and that those from the liver of Case II. and the spleen and intestine of Case III. are also identical. All the others are different from these, from one another, and from the organisms isolated in the case of Chick I., Table I. (*q.v.*).

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